Exploring Beliefs and Practices Towards Teaching Probability Using Games: A Case Study of one Fijian Secondary Mathematics Teacher

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Probability requires teaching approaches that allow children to predict, observe and experiment with concreate materials, games and simulations. In this study, we explored one teacher's beliefs and practices of teaching probability using game-based approaches. We employed a design-based research approach to explore how our case study teacher engaged with an hour-long professional learning on using a game-based probability teaching sequence. We found that our case study teacher's espoused beliefs and self-reported practices aligned with knowledge of teaching probability demonstrated during the professional learning activity.

In probability teaching, teacher beliefs, and knowledge are one area of concern (Batanero et al., 2004). Issues such as over emphasis on teaching procedural tricks, and lack of confidence in teaching probability exist, which lead to a lack of understanding and motivation for learners. (Sharma, 2015). According to Batanero et al. (2004), there are six main areas of teacher knowledge for teaching probability. Epistemic content represents knowledge of probability and statistics content, while cognitive and affective components broadly represent what Shulman (1987) called knowledge of student cognitions. The other three categories are media, interactional and ecological components. These components highlight some of the main pedagogical resources that are required by teachers. Unlike other branches of mathematics, probability requires relatively greater use of technological resources and an understanding of a wider range of applicability of the content in our everyday and professional lives (Estrada Roca & Batanero, 2020).

An important part of teacher knowledge includes having a productive disposition towards teaching probability. According to Estrada Roca and Batanero (2020), success of curriculum depends on teachers' interest in teaching probability. Estrada et al., (2020) provide a useful framework for understanding teachers' beliefs. Their framework explores beliefs about probability as well as the teaching of probability under three domains: affective (for example, teachers' emotions towards probability and its teaching), cognitive competence (for example, teacher's self-awareness of probability concepts and how to teach them) and behavioural (for example, is the teacher eager to teach probability). An added domain is value towards probability and its teaching (for example, does the teacher give importance to probability as a subject). Teacher knowledge and beliefs can be enhanced if they are exposed to a variety of teaching approaches (Koparan, 2022).

In this paper, we explored one Fijian secondary mathematics teacher's beliefs towards probability teaching before and during participation in professional development on a games-based teaching approach. Current approaches to teaching probability in the Fijian secondary classroom context generally rely on the traditional chalk-and-board style of teaching. In other words, probability teaching in the Fijian context does not take advantage of game-based teaching approaches that have connections with students' everyday experiences. This study is important because engaging teachers in games is likely to help develop their knowledge.

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Theoretical Orientation of the Study

We used Vygotsky's socio-cultural theory which states that knowledge is socially situated and constructed through interactions with people (Vygotsky & Cole, 1978). In other words, knowledge construction requires tools such as language and cultural artefacts such as games. The socio-cultural views of learning see the role of the knowledgeable other such as peers as important. Also, viewed from a socio-cultural lens, teaching is a social activity that requires co-construction that often involves scaffolding from the knowledgeable other (Bell, 2010).

In other words, working together in collaborative practices and engaging in formative interactions with one another can enhance teachers' cognitive growth (Vygotsky & Cole, 1978). In our larger study, the teacher participants and the researchers provided the platform for our case study teacher to engage with a game-based probability teaching sequence and reflect on its usefulness. Our study involved an hour-long professional learning session and the socio-cultural view of learning gives us an opportunity to see how our case study participant contributed to knowledge construction of others. Given that probability teaching involves different dimensions of knowledge, including affective dimension, the socio-cultural theory provided us with a useful lens to explore our participants' beliefs towards probability as well, because human behaviour is highly influenced by cultural contexts and interactions (Moll, 2013, p. 16).

Literature Review

Two major interpretations of probability exist. Firstly, the theoretical viewpoint claims that all possible outcomes can be attributed to their own probabilities. On the other hand, the experimental probability acknowledges that the probability of an event happening can be determined by conducting experiments (Jones et al., 2007). Research literature provides some useful instances of how games can provide a useful context for exploring different interpretations and contexts suggested by Jones et al. (2007). One such example is provided by Batanero et al. (2004) who show how different probability teaching contexts can be explored using game-based teaching approaches. Having engaged a group of teachers in a game involving different coloured dice, they speculate that teachers do acquire knowledge that would be beneficial in their later professional work. Most of the research conducted with teachers, including prospective teachers, suggest that teachers find teaching probability and statistics difficult or challenging (Batanero et al., 2004; Leavy et al., 2013). Findings from a small sample study conducted by Leavy et al. (2013) in Ireland suggest that prospective secondary mathematics teachers perceive statistics as a challenge due to, among other factors, the need to think and reason statistically. Some studies also report similar findings with respect to both prospective and practicing teachers' understandings of probability (Estrada Roca & Batanero, 2020; Kazak & Pratt, 2017) as well as their understandings of teaching probability (Batanero & Álvarez-Arroyo, 2024; Batanero et al., 2010). Many studies have reported that children find probability to be a difficult topic and as a result show a number of misconceptions (Koparan, 2022; Sharma, 2015).

While the literature points out many challenges with respect to probability teaching and learning, it also points to some initiatives that can help overcome some of these challenges. Introducing teachers to activities that help uncover the relationship between theoretical and experimental aspects of probability is one such area. Typical activities proposed in the literature range from 'classical paradoxes that appeared in the history of probability' (Batanero et al., 2010; Estrada Roca & Batanero, 2020) to more recent innovations such as games (for example, tokens, cards, lotto, board, embodied, or cultural games) (Dayal & Sharma, 2021) or computer-generated games and simulations (Koparan, 2022). The use of a varied range of teaching activities such as games and computer-based simulations, models and experiments can provide excellent contexts for teaching probability (Dayal & Sharma, 2021), help teachers make links

between statistics and probability (Estrada Roca & Batanero, 2020), and mediate theoretical and experimental probability (Kazak & Pratt, 2017). Estrada Roca and Batanero (2020) claim that many teachers have studied theoretical probability, which is one reason they may lack expertise in designing rich games and activities for the classroom. Exposure to rich activities has led to positive beliefs in teachers (Estrada Roca & Batanero, 2020). Other studies such as Batanero and Álvarez-Arroyo (2024), Batanero et al., (2010), Kazak and Pratt (2017) and Koparan (2022) confirm the many benefits of engaging teachers in such rich activities. Other studies, such as Veloo and Chairhany (2013) and Sullivan (2020), confirm the benefits of engaging children in such games.

Teaching probability and statistics is also a challenge for Pacific Island teachers. Dayal and Sharma (2020) reported that pre-service secondary mathematics teachers made incorrect predictions on a probability teaching sequence initially but were able to correct those misconceptions after conducting the experiments. Findings also revealed that pre-service teachers enjoyed the game-based teaching sequence because of the affective and cognitive learning challenges and opportunities it provided, as well as providing ideas for future teaching (Dayal & Sharma, 2021). This study hopes to add to our understanding of how in-service teachers can derive potential teaching ideas for both theoretical and experimental aspects of probability. The literature seems to suggest general prevalence of teaching challenges as well as an acknowledgement of the potential benefits of teaching using games. The current study also aims to add to our understanding of in-service teachers' perceptions of the degree of usefulness of games in teaching from a Pacific Islands context.

Methodology

For the purpose of this paper, we used a case study research methodology. Case study is the study of a unique stance in action (Cohen et al., 2007). In this study, a case study approach helped us provide a 'close-up reality' of the beliefs, knowledge and lived experiences of teaching probability of one secondary mathematics teacher.

The study reported in this paper involves only one teacher. Our participant, Jone, is a relatively inexperienced teacher with only two years of teaching experience at a single urban school. He recently graduated with a Bachelor of Science and Graduate Certificate in Education (BSCGCED) majoring in mathematics and physics. During the professional learning workshop, Jone partnered with another teacher from his school. The larger study consisted of 15 Fijian secondary mathematics teachers who went through three related phases: a pre-workshop one-to-one interview; an hour-long workshop; and a post workshop written reflection and interview. Details of the workshop can be seen in Table 1. A case study methodology was suitable because it allowed us to study one teacher's views and practices (Yin, 2009) in greater detail. The data collection was done in multiple ways that included a 15-minute-long interview, followed by an hour-long professional learning workshop. The final source of data reported in this study came from written reflections and a short interview at the end of the workshop. All interview data was audio recorded while the professional learning workshop was video recorded. Jone's interviews were analysed by deriving themes from different focus areas in the interviews. In describing Jone's workshop participation, we describe his actions based on the different parts of the workshop such as *posing a problem*, *playing the game in pairs* and *planning and exploring*. We purposively chose Jone as our case-study for this paper for two reasons: firstly, Jone was the least experienced of the 15 participants. Secondly, Jone had expressed his strong support for using games-based approaches in teaching during the initial interview, and as we report in the next section, Jone was highly influential during the workshop as well. The findings are presented next, in the same order as the research unfolded.

Table 1

A Game-Based Probability Teaching Sequence

Parts	Activities	Reflection and discussion
1: Posing a problem (Approximately 10 minutes)	Esha and Sarah decide to play a die rolling game. They take turns to roll two fair dice and calculate the difference (bigger number minus the smaller number) of the numbers shown. If the difference score is 0,1,2 Esha wins. If the difference score is 3, 4, 5, Sarah wins Is the game fair?	Why do you think the game is fair (or unfair). Explain your thinking
2: Playing the game in pairs (Approximately 20 minutes)	In pairs (or groups), teachers play the game with at least 20 trials	Is the game fair? Why or why not?
3: Planning and exploring (Approximately 30 minutes)	Pairs (or groups) make a plan to collect, record and analyse more data	Is the game fair? Why or why not? Think of the activity you just did. Can you share your views about this activity? Would you use this type of teaching sequence in your teaching? Where and how? What would be some of the benefits and challenges?

Findings

Jone's Views and Practices about Teaching Probability

During the interview, Jone began by acknowledging that he was new to the mathematics teaching profession. At the same time, he expressed having confidence in teaching probability. He stated that probability was a relevant topic for students because of its importance 'to our daily lives'. He argued that probability is closely linked to our day to day living and students tend to enjoy this topic in comparison to other mathematical topics. Jone also expressed that probability is one topic that involves both practical and theory. As such, he expressed strong views that probability be taught using practical activities along with normal pen-paper questions, "for me, it is something that we cannot just teach on paper … I have always used practical and demonstrative methods to teach students." He continued by sharing examples of using "certain coins, dice or spinner" to teach his students. He reiterated the need for teachers to "get the hands on experience" or using "real life examples of using weather or using the probability of an event they can relate to." Jone also showed greater understanding of the probability curriculum and mentioned that he has actually compared some aspects of the Fijian and NZ mathematics curriculum.

Upon further probing, Jone revealed that he has already conducted practical activities with his year 10 class. This activity involved a single die "we did play a few games and that involved a game of … we used to roll a die and students noted down the outcomes and we compared the outcomes and how frequently do we get a particular outcome."

When asked to share if he had used any other activity, Jone described the following:

> Each group was paper, pens to write and two dice. And the students were asked to roll the dice and to note down the outcome for each roll and for both dice and then we compared what is the difference in the outcome of both dice.

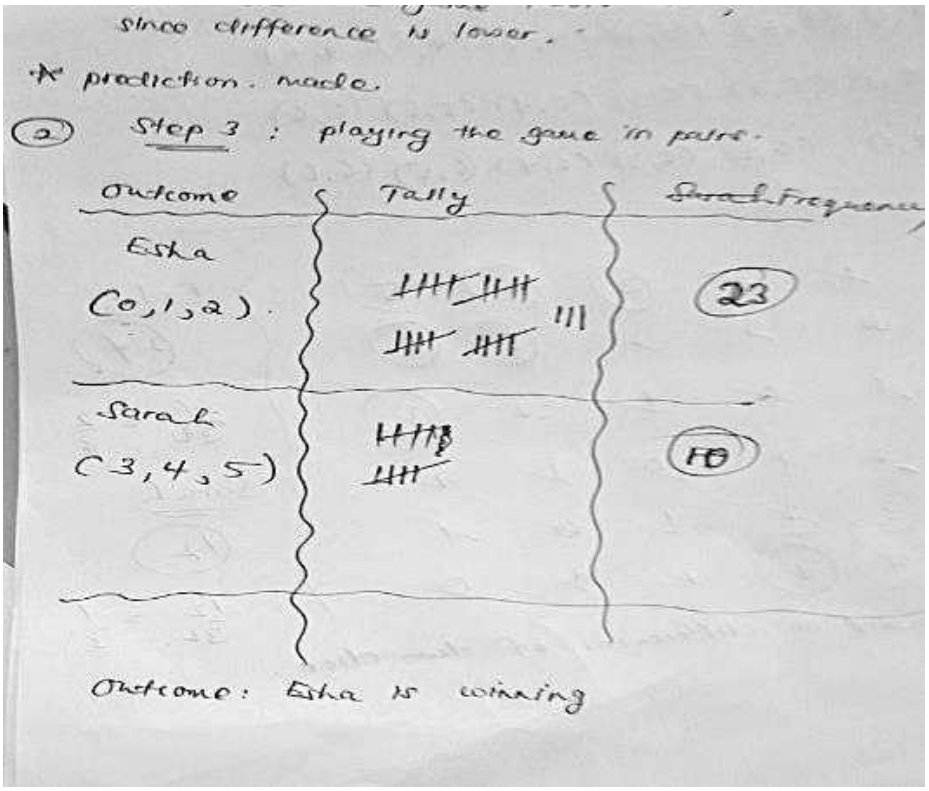
Jone reported that this activity was carried out with Year 10 students and they (the students) were able to find the sum and difference of two dice successfully. This was an interesting finding because the same idea of 'difference of two dice' formed the basis of our professional learning workshop. The workshop activity then provided us with an opportunity to learn more about Jone's self-reported teaching practices and validate his claim, especially the fact that he had some ideas about using the difference between the two die activities from his teaching experience with Year 10. How Jone participated in the workshop is described next.

Jone's Workshop Participation

During the workshop, we noticed that Jone became a resource not only for his group, but his initial predictions and his demonstrations during the workshop were found to be useful by other teachers that participated in the workshop

Figure 1

Jone's Trial Data



In 'posing the problem' part, Jone was the only teacher who was able to state that the game was not fair. He stated that "the game is not fair because they don't have an equal probability of winning. Most cases, the game favours Esha, since the difference of lower numbers is more". In part 2 of the activity, Jone conducted 33 trials with his team members and recorded the data, as shown in Figure 1. In order to convince his team member, Jone and his partner did some more trials until the team member was convinced that Esha was winning more often. Jone was able to offer a theoretical explanation by listing all the possible outcomes when two fair dice are tossed (see Figure 2). Next, he created a figure that showed the numerical difference between the outcomes of the two dice from Figure 2. The outcomes for Sarah were circled as shown in Figure 3 while the ones crossed were outcomes for Esha. The theoretical probabilities for both Esha and Sarah were counted out of the possible 36 outcomes and reduced to the simplest fraction.

Figure 2

Jone's Representation of Possible Outcomes When Tossing two Dice

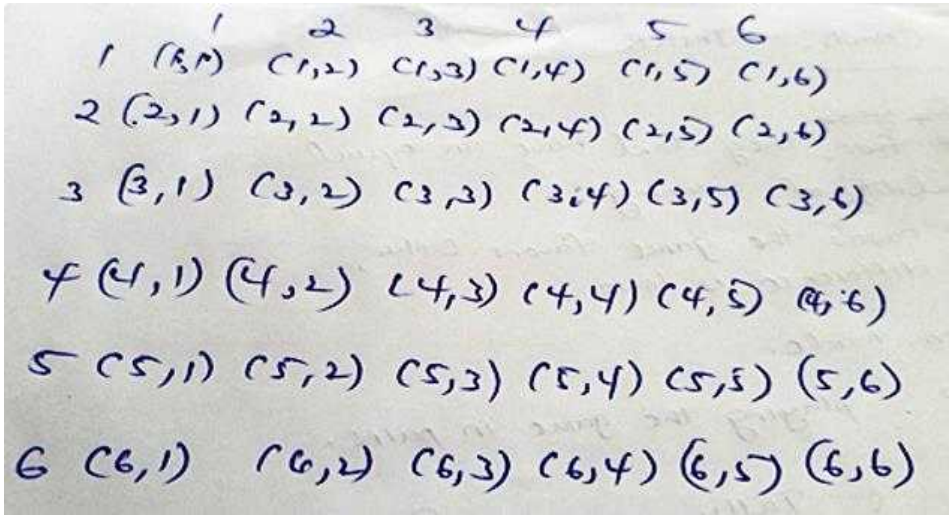
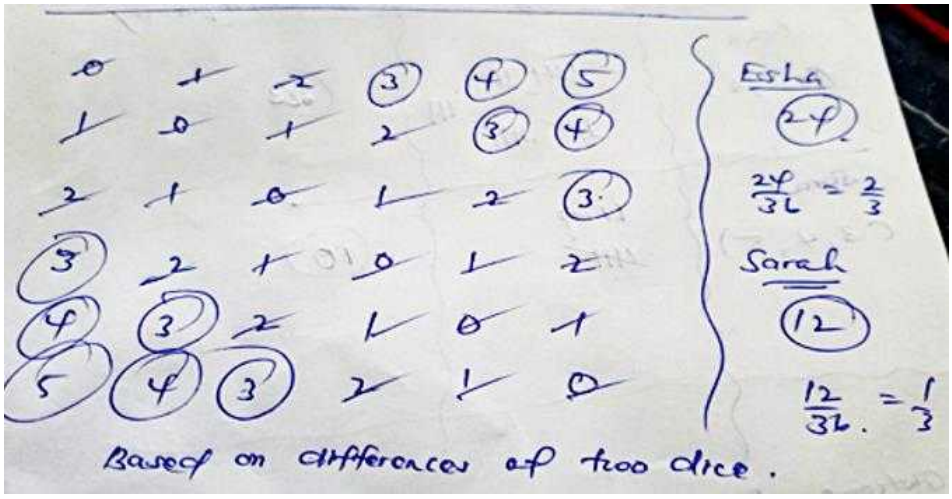


Figure 3

Jone's Understanding of Calculating Theoretical Probability When Tossing two Dice



Jone's Final Reflections

At the end of the workshop, we asked Jone to share his view on the probability teaching sequence, its applicability to classroom teaching, and associated challenges and benefits, and his intentions about using such techniques in future teaching. He expressed that the probability teaching sequence was a good opportunity for the teachers to learn to analyse the fairness of a game. He was able to suggest a number of activities that could be derived from this probability teaching sequence. For example, one of the interesting suggestions included using the same probability teaching sequence to teach about 'unfair gaming systems' and about outcomes that are 'not equally likely' outcomes. In addition, some common probability concepts listed were sample space, probability of an event, and probability distribution of each outcome. He was able to relate some of his ideas to actual classroom topics when he mentioned "Year 10-trials and experiments' and 'year 11-probability of an event". Jone stated several benefits such as "concrete learning, active learning, visual representation and engagement". In addition, he noted challenges such as large class sizes and varying levels of student understanding. He acknowledged that the probability experiments might be difficult for some students because

they might find it difficult to "understand the results of the activity". Despite these challenges, Jone said that he will be using the probability teaching sequence in his teaching in the future and talked about sharing the idea with other department teachers at his school.

Discussion

This study examined one teacher's beliefs about teaching probability and his self-reported teaching practices, followed by an hour-long engagement with a game-based probability teaching sequence. The findings of this study reveal that Jone held strong views about the usefulness of probability and argued in favour of using games and demonstrations in teaching probability. He showed an awareness that probability demands a slightly different approach to teaching because it involves theoretical and experimental aspects. Jone, in reporting his style of teaching probability had revealed that he had already tried the probability teaching sequence with his Year 10 class.

The findings are interesting because previous studies done in Fiji and NZ using the same probability teaching sequence (Dayal & Sharma, 2021; Dayal & Sharma, 2020) albeit with pre-service teachers, show that pre-service teachers were not able to make the correct prediction at the start. They were, however, able to correct their responses after carrying out the trials. Our personal experiences of conducting professional learning workshops with secondary mathematics teachers in Fiji over the last couple of years reveal similar findings-i.e., practicing mathematics teachers see the game as fair and perceive the difference scores to be equally distributed. Another interesting aspect is that while pre-service teachers struggled to mention how they could use the probability teaching sequence in their actual teaching (Dayal & Sharma, 2020), Jone was able to state at least five quick ways of applying the lessons learnt from the workshop to his classroom teaching. Also, in his interviews, he stated that he was using similar activities for Year 10 students. In the Fijian mathematics teaching context, this is somewhat rare as previous studies in Fiji (Dayal & Sharma, 2020) and elsewhere (Batanero et al., 2004; Estrada Roca et al., 2020; Koparan, 2022) reveal that teachers themselves find such game-based probability teaching sequence quite challenging. Studies done with students also reveal that students find probability to be a challenging topic (Koparan, 2022). On the contrary, Jone reported that students in his class generally enjoyed probability. When asked to list some challenges when implementing this probability teaching sequence in Fijian classrooms, Jone acknowledged that some students might find the activity difficult. We speculate that teachers are unlikely to use game-like activities as teaching resources if they are uncomfortable in carrying out the activities themselves.

Conclusion

The research finding reported in this paper is based on a single case study. One limitation of the study is that its findings cannot be generalised. The findings provide us better insights into one teacher's beliefs, his self-reported practices and epistemic content knowledge as well as cognitive and affective components of knowledge for teaching probability (Batanero et al., 2010). The study's findings also support the need for teachers to have other dimensions of knowledge for teaching probability such as having a productive disposition towards teaching probability. Studies such as Estrada Roca and Batanero (2020) state the importance of factors such as teachers' interest in teaching probability. Previous research findings suggest that effective teaching of probability requires making greater use of resources in teaching probability such as using media, interactional and ecological components of teacher knowledge (Batanero et al., 2010). Our case study teacher, who held productive beliefs about teaching probability, and claimed to have made use of greater resources showed an advanced understanding of probability teaching through his participation in our probability teaching sequence. We speculate that our case study teacher would have interacted more with media, interactional and ecological components in order to build his knowledge of probability teaching.

We conclude that exposure to rich activities can lead to improved knowledge for teaching probability, including positive beliefs towards teaching.

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